Comments on ET Docket No. 03-137, NPRM on RF Exposure

Topic: Measurement Uncertainty

Summary: *RF field level measurements will always have a significant amount of measurement uncertainty even when the measurements are made by a skilled surveyor using the best available instruments. Measurement uncertainty has three major components:*

1. *Measurement uncertainty due to the instrumentation.*
2. *Perturbation of the field by the surveyor.*
3. *Time and spatial variations in the field.*

The following comments discuss measurement uncertainty related to the broadband instrumentation that is most commonly used to make RF safety field level measurements.

Instrument Design

Virtually all RF safety measurements are made with broadband instruments comprised of a probe and a meter. The accuracy of a survey instrument is almost entirely driven by the accuracy of the probe. Most probe specifications are expressed in dB. A parameter that has a 1.0 dB tolerance means the value could be off by 26 percent. In contrast, even a simple meter should be accurate within a maximum of 5 percent.

Frequency deviation is the most important parameter that contributes to the amount of measurement uncertainty but it is not the only parameter that should be considered. The FCC regulations and all of the major worldwide standards have exposure limits that vary as a function of frequency. The growth of wireless services and deployment of digital television have both led to a growing number of sites that have multiple emitters operating at frequencies with different Maximum Permissible Exposure (MPE) limits. This has led to the use of shaped frequency response probes as the primary tool used for surveys of wireless and broadcast sites.
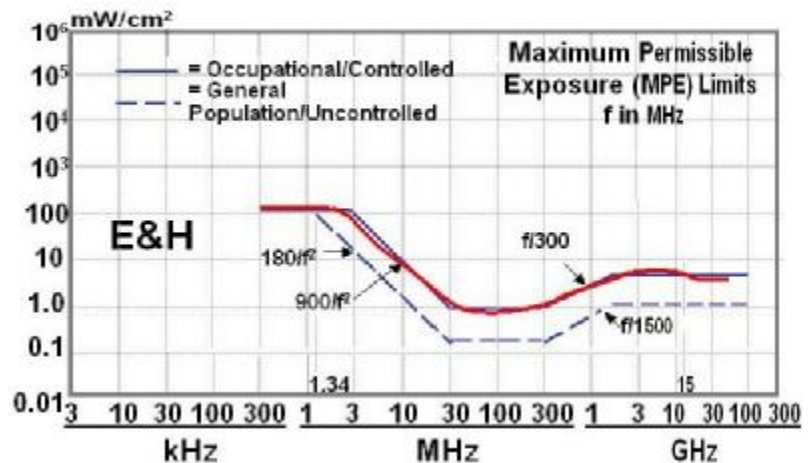
Shaped frequency response probes are designed so that sensitivity at the point of detection varies over their frequency range. The goal is to match a standard, such as the FCC regulations, as closely as possible. Narda Microwave holds the patent on this technology, which is accomplished in a manner similar to designing a filter. It is impossible to make the sensitivity match the MPE limits exactly. The greatest errors tend to occur at the transition points where the MPE limits change from a constant to a slope or vice versa. In the FCC regulations for Occupational/Controlled exposure, these transition points occur at 3 MHz, 30 MHz, 300 MHz, and 1,500 MHz.

The red line shows the typical frequency response of a Narda 8700 series shaped frequency response probe.

Note that the biggest deviations from the FCC MPE limits occur at the transition points. The design of the RC circuits causes the response to "round" at these points.

These probes include calibration frequencies at or near each of the transition points.

FCC 1997 Regulations

mW/cm²

= Occupational/Controlled
= General Population/Uncontrolled

Maximum Permissible Exposure (MPE) Limits
f in MHz

E&H

$180/f^2$
$900/f^2$
$f/300$
$f/1500$

10^6 10^5 10^4 10^3 100 10 1.0 0.1 0.01

1.34   15

3 10 30 100 300 1 3 10 30 100 300 1 3 10 30 100 300
kHz   MHz   GHz

Defining Accuracy

It is almost impossible to define the overall accuracy of a survey instrument because accuracy depends on not only the instrument but also on what is being measured and the techniques that are used to make the measurements. The best that one can do is to estimate the overall measurement "uncertainty" for a particular set of conditions and determine that the uncertainty is valid providing that the equipment is used properly. There are several parameters that should be considered when attempting to establish the level of measurement uncertainty. The parameters are listed in order of importance; i.e. the parameters that can result in the greatest uncertainty are listed first. The list assumes that the probe is well-designed and appropriate for the measurement task.

Parameter	Potential Uncertainty	Comments
RMS Detection	Overestimate by 10 dB or more in multiple-emitter environments.	It is not important to have a probe work in the "square law" region if you are measuring a single frequency. Measurements at a multiple emitter site should be made with a probe's detectors functioning within the square law region.
Frequency Sensitivity	Should be <2dB but can be >10 dB.	Are the specifications guaranteed or typical? The reference point for shaped frequency response probes should be the *standard*, not a theoretical best-case curve!
Calibration Frequencies	Limited to the specified frequency sensitivity providing that multiple-frequency calibration is used to verify performance.	Single-frequency calibration makes the assumption that all similar probes function within specified tolerance limits. This is a big assumption.
Isotropic Response	Should be <±1½ dB.	Check probe specifications.
Ellipse Ratio	Should be <±¾ dB.	Check probe specifications.

As previously stated, the major component of measurement uncertainty for a probe is normally its frequency deviation. The Narda Safety Test Solutions Model A8742D probe used by this consultant is calibrated at 14 different frequencies to guarantee that the frequency deviation—error versus frequency—is a maximum of ±2 dB. The other parameters, such as ellipse ratio and isotropic response, are less significant than frequency deviation but cannot be ignored. *A good rule of thumb*

when making measurements in multi-signal environments with this type of equipment is to assume an uncertainty of ±3 dB.

The ±3 dB figure for measurement uncertainty is only applicable for the Narda 8700 series shaped frequency response probes. These probes are tested at multiple frequencies and have a guaranteed maximum deviation of ±2 dB over their entire frequency band. The other brand of shaped frequency response probes is also supplied by Narda Safety Solutions. The Type 25 FCC-shaped probe is used with the EMR series of meters. This probe *does not have a guaranteed maximum frequency response error*. Most of these probes have been sold with only a single-calibration frequency at 100 MHz.

Even when a probe has been calibrated at multiple frequencies, this only assures that the probe frequency deviation is within specification unless one is measuring a site with only one emitter. If measurements are made where there is only a single emitter or where all emitter frequencies are very close to each, as is the case at a site with only cellular service, a correction factor can be used to reduce the amount of measurement uncertainty. In more complex environments, the additional calibration frequencies only provide a rough indication of frequency deviation.

For single-frequency measurements where an appropriate probe calibration factor can be used, it is possible to eliminate most of the frequency deviation from the uncertainty. This reduces overall measurement uncertainty to about ±1 dB. It is important to understand the characteristics of the probe to use the correction factors correctly. A shaped frequency response probe has its greatest errors in the transition regions near 3 MHz, 30 MHz, 300 MHz, and 1,500 MHz where the probe's sensitivity changes sharply over frequency. The use of correction factors is less accurate when one attempts to interpolate between two calibration frequencies near the transition regions of the probe.

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